REVIEW ARTICLE

Emerging and Exotic Zoonotic Disease Preparedness and Response in the United States – Coordination of the Animal Health Component

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Impacts

- This article outlines the preparedness and response measures to be taken by the U.S. competent veterinary authority for a zoonotic disease outbreak.
- Knowledge of the means, measures and underlying rationale for the animal disease approach will assist public and veterinary health researchers and policy makers in partnering to achieve mutual goals.
- An integrated approach to prevention, preparedness, response and recovery is needed. Recent events have strengthened a unified approach, but more needs to be done.

Keywords:
Zoonoses; foreign animal diseases; infectious disease; veterinary medicine; preventive medicine; influenza

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Summary

For the response to a zoonotic disease outbreak to be effective, animal health authorities and disease specialists must be involved. Animal health measures are commonly directed at known diseases that threaten the health of animals and impact owners. The measures have long been applied to zoonotic diseases, including tuberculosis and brucellosis, and can be applied to emerging diseases. One Health (veterinary, public, wildlife and environmental health) and all-hazards preparedness work have done much to aid interdisciplinary understanding and planning for zoonotic diseases, although further improvements are needed. Actions along the prevention, preparedness, response and recovery continuum should be considered. Prevention of outbreaks consists largely of import controls on animals and animal products and biosecurity. Preparedness includes situational awareness, research, tool acquisition, modelling, training and exercises, animal movement traceability and policy development. Response would include detection systems and specialized personnel, institutions, authorities, strategies, methods and tools, including movement control, depopulation and vaccination if available and appropriate. The specialized elements would be applied within a general (nationally standardized) system of response. Recovery steps begin with continuity of business measures during the response and are intended to restore pre-event conditions. The surveillance for novel influenza A viruses in swine and humans and the preparedness for and response to the recent influenza pandemic illustrate the cooperation possible between the animal and public health communities.

Abbreviations: APHIS, Animal and Plant Health Inspection Service; ARS, Agricultural Research Service; CDC, Centers for Disease Control and Prevention; DHS, Department of Homeland Security; FAD, Foreign Animal Disease; FMD, Foot-and-Mouth Disease; HHS, Department of Health and Human Services; HPAI, Highly Pathogenic Avian Influenza; ICS, Incident Command System; NVS, National Veterinary Stockpile; OIE, World Organization for Animal Health (historical acronym); PPRR, Prevention, Preparedness, Response, Recovery; USDA, United States Department of Agriculture; VS, Veterinary Services.

Background

Zoonoses are caused by agents ranging from prions to helminths and are transmitted by routes ranging from aerosol and oral to potentiating arthropod vector. Infected non-human vertebrates (animals) may be the primary source of human infections, the origin of a disease that spreads primarily from person-to-person, dead-end hosts or the result of human-to-animal transmission. Infection in the animal host may cause severe, mild or no disease and have a significant or no effect on food safety. The preparedness and response measures for the various zoonosis situations must, therefore, overlap but differ. To narrow the focus, this article will deal primarily with the preparedness for and response to an outbreak of non-food-borne zoonoses that would also cause disease in U.S. animals.

Recent zoonotic threats and events have highlighted the need for a One Health approach. The One Health approach integrates communication, collaboration and coordination between public health, animal health and other communities at multiple levels to prevent, detect and control emerging or re-emerging infectious diseases at the animal–human–environment interface. The knowledge, strategies, economics and public perceptions involved in the animal disease response can be similar to those for the disease in human populations (e.g. pathogenesis research, quarantine, vaccination) or very different (e.g. depopulation). Actions by the animal health community would reduce the spread or shed in animals, which would lessen morbidity and mortality in animals, lessen the economic impact on producers and preserve food security. It would also reduce the exposure and risk to people, curtailing the public health impact of the disease. Describing the underlying rationale and methods for the animal health response may add to the dialogue needed to plan, prepare and respond to zoonotic outbreaks.

Confronting Zoonotic Threats

Zoonotic disease threats

Certain zoonotic threats have been included in overlapping high-priority threat lists, resulting in plans and countermeasures being prepared for them. For the animal component, a frequently cited list is the Animal and Plant Health Inspection Service (APHIS) National Veterinary Stockpile (NVS) most damaging animal diseases list, which includes zoonotic diseases. In priority order, they are highly pathogenic avian influenza (HPAI, fatal zoonotic), foot-and-mouth disease (FMD, essentially non-zoonotic), Rift Valley fever (RVF, fatal zoonotic), exotic Newcastle disease (END, mild zoonotic), Henipaviruses (fatal zoonotic), classical swine fever (CSF, non-zoonotic), African swine fever (non-zoonotic) and 10 others (APHIS, 2009a). In addition, certain animal diseases are listed in the *Code of Federal Regulations* (CFR) as being foreign to the United States (foreign animal diseases, FAD), including the zoonotic diseases caused by *Burkholderia mallei* (glanders) and HPAI (Anon, 2002a).

The U.S. Select Agent and Toxins List [APHIS and Center for Disease Control and Prevention (CDC), 2011] includes three lists of agents germane to the topic. The U.S. Department of Agriculture (USDA)–APHIS–Veterinary Services (VS) list includes zoonotic agents (e.g. HPAI and bovine spongiform encephalopathy, BSE). The U.S. Department of Health and Human Services (HHS) list also includes zoonotic agents (e.g. *Francisella tularensis* and *Yersinia pestis*). The HHS and USDA Overlap agents list is comprised of 10 zoonotic agents, for example, RVF, Henipaviruses, *Bacillus anthracis*, *Brucella abortus* and Venezuelan Equine Encephalitis virus (VEE). The CDC Bioterrorism list, with categories A, B and C also includes certain fatal zoonotic agents. Examples of the listed agents include, for example, *B. anthracis* and *Y. pestis* within category A, *Brucella* spp., *B. mallei*, Q fever and VEE within category B and Nipah virus within category C (CDC, 2011).

However, a new or emerging zoonosis (i.e. a disease not specifically listed) could also become a high-priority disease with plans and countermeasures applied. An emerging zoonotic disease could quickly be added to a list. The proposal for a U.S. National List of Reportable Diseases includes a provision for adding emerging diseases, and zoonosis is one of the considerations for doing so (Elvinger and Becton, 2010). The World Organization for Animal Health (OIE) language for immediate (24 h) notification for specific high-impact diseases also includes 'an emerging disease with significant morbidity or mortality, or zoonotic potential' [World Organization for Animal Health (OIE), 2010]. That is how the 2009 pandemic influenza [A(H1N1) pdm09] virus infection detections in swine in the United States and elsewhere were reported to the OIE (OIE, 2009a). The World Health Organization (WHO) international health regulations (IHR) also require State Parties to notify WHO immediately (within 24 h) of detection of four diseases (including human influenza caused by a new subtype) and events (including those of unknown causes or sources) with the ability to cause serious public health impact and to spread internationally (World Health Organization, 2005).

Finally, taking action and applying or deploying U.S. tools are not dependent on a disease being on a list. For example, in a large outbreak of any disease, the USDA Secretary could declare an extraordinary emergency, making additional funds available to deal with the situation.

Preparing for and detecting an emerging disease are ongoing concerns. Improvements in syndromic surveillance (Vourc'h et al., 2006; Amezcua et al., 2010), wildlife disease surveillance [Government Accountability Office (GAO), 2010] and biosurveillance integration (Mauer and Kaneene, 2005; Anon, 2007; GAO, 2010) are needed to aid emerging disease detection. Diagnostics based on known microbe taxa sequences to detect the unknown or unexpected have been applied (Barrette et al., 2009). These are aided by the burgeoning sequence information available, including that from metagenomics. Pathogen discovery programmes (Lipkin, 2008), also including metagenomics (Day et al., 2010), are beginning to be employed in animal health. If the disease were discovered in another country first, it would enable better prevention and preparation in the United States. Once detected, many of the response plans, methods and tools for known diseases could be applied to an emerging disease.

The animal health infrastructure including APHIS–VS

An extensive infrastructure including state–federal animal cooperative disease control programmes, regulations, laboratories and other tools has been constructed for domestic animal health. The infrastructure exists primarily for the benefits of animal companionship, the economics of animal protein production in the United States and trade in livestock and animal products. However, the infrastructure has an additional, public health, benefit. The benefit can be attributed to the potential for animal disease agents to mutate in or expand in agricultural species and settings (Ito et al., 2001; Spackman et al., 2003) and to infect humans in those settings (Myers et al., 2007; Gray et al., 2008). The domestic animal health systems can also be applied to wildlife diseases [e.g. avian influenza (AI) in waterfowl; chronic wasting disease in captive and wild cervids; rabies in raccoons, skunks and coyotes; tuberculosis in deer; brucellosis in bison and elk; and Aujeszky's disease in feral swine].

Preparedness and response are central to the U.S. animal health agency responsibilities. The Animal Health Protection Act (AHPA) (Anon, 2002b) states that '…prevention, detection, control, and eradication of diseases and pests of animals are essential to protect – animal health, public health, as well as environmental health, the economic interests of the livestock industry, and interstate and international trade'. The Virus-Serum-Toxin Act (VSTA) (Anon, 2005) as amended regulates the manufacture and sale of all vaccines and other biologics for all animal species. USDA–APHIS–VS administer both Acts.

In addition, all five of the VS2015 goals (transform VS culture, build new collaborations and partnerships while sustaining existing ones, optimize and leverage animal health competencies, support readiness and response, and invest in technical infrastructure) relate to the APHIS–VS preparedness and response role in a zoonotic outbreak. Particularly noteworthy for this discussion is the goal 'Support readiness and response, balancing the needs of animal agriculture with the interests of people and the environment' (APHIS, 2011a). Two of the foci in the development of the VS2015 vision were Agricultural Emergency Management Preparedness and Response Planning, and One Health. The One Health Initiative of the American Veterinary Medical Association and the American Medical Association (American Veterinary Medical Association, 2008) rejuvenated the historic One Medicine concept (Kahn et al., 2007). Currently, this concept includes public, veterinary, wildlife, environmental and social health (including food security and often sustainability).

Partnerships

Although this discussion focuses on APHIS–VS actions, the actions and accomplishments rely on extensive alliances. APHIS–VS partners with other national animal health authorities on transboundary disease issues and actions. Partnerships with global organizations include those with the WHO (e.g. IHR, alerts), including the regional Pan American Health Organization (whose Pan American Foot and Mouth Disease Center deals with FMD control and eradication for food security). Partnerships also include the United Nations Food and Agriculture Organization (FAO, including reference centres, international assistance) and the OIE (e.g. diagnostic methods and reporting, reference centres, assessing veterinary infrastructure for safe trade). Other international partnerships include the North American Animal Health Committee (Canada, Mexico and the United States) and the Quadrilateral Animal Health Committee (Australia, Canada, New Zealand and the United States).

Partners in the U.S. government (and example activities) include the Departments of Homeland Security (DHS, port inspection, countermeasure transition and high biosecurity laboratories), HHS (basic research, surveillance and epidemiological investigations), Interior (wild bird AI surveillance), Defense (food security in countries where the damaging diseases are endemic), the Environmental Protection Agency (EPA, disinfection, disposal), the Federal Bureau of Investigation (agroterrorism investigation) and other members of the intelligence community (information on biotechnology, infectious disease and countermeasures). APHIS–VS also partners directly with other USDA agencies, including the Agricultural Research Service (ARS) and National Institute of Food and Agriculture on research, laboratories and extension.

It collaborates with Food Safety and Inspection Service (FSIS) on pre- and post-harvest food safety. The organization also works with other USDA agencies on international, economic, geographical and statistical, and disaster response issues.

The federal–state animal health partnership is critical to ongoing control and eradication programmes. In the United States, the standard incident command system (ICS) structure for animal health response efforts is a federal–state joint command. The NVS has conducted animal health emergency deployment exercises with States and the Navajo Nation (APHIS, 2011b). Partnerships with academia reveal information gaps or potential tool improvements and provide the research needed to fill knowledge gaps. Partnerships with the animal industry provide information on vulnerabilities, movement and marketing methods, as well as human and countermeasure resource needs.

In many cases, important players in preparedness and response are linked in multiple ways. For example, state animal health agencies partner with their state public health, emergency management, transportation, fish and wildlife, and environmental protection agencies and with universities, particularly state universities and extension services. APHIS–Wildlife Services partners with the Department of Interior and state fish and wildlife agencies. As another example, ARS and DHS partner with commercial biologics and biotechnology companies and entities such as the National Aeronautics and Space Administration and National Oceanic and Atmospheric Administration. FSIS partners with the Food and Drug Administration of HHS. The CDC partners with international, state and local public health officials; health practitioners; university researchers; and non-profit organizations. As a final example, the Federal Emergency Management Agency (FEMA) of DHS partners with non-governmental organizations. Coordination and plans are important as many partners contribute to the effort.

The roles and responsibilities of APHIS–VS and its partners have become clearer and more defined as a result of events (not all of which have been zoonotic or even primarily animal health events) over the past decade. In 2001, bovine brucellosis and bovine tuberculosis had been nearly eradicated from the U.S. cattle herd. The near eradication of these diseases marked a long-term success for animal health and zoonotic disease organizations and provided an opportunity to re-examine methods, resources and priorities. In addition, the economic, social and trade impacts and publicity of the 2001 United Kingdom FMD outbreak, as well as the virological, epidemiological and trade impacts of the 1997 Taiwan outbreak and the South American experience with eradication, caused a re-examination of U.S. animal disease control and eradication methods. The 9/11 (2001) attacks resulted in the formalization and generalization of the National Incident Management System (NIMS), the ICS and the Multi-Agency Coordination System (MACS). In 2002 and 2003, the California END outbreak ingrained these systems in animal health emergency response. Pandemic influenza preparedness (H5N1) from 2004 to 2009 and the influenza pandemic A(H1N1)pdm09 in 2009–2010 established or highlighted many of the One Health partnerships and systems required in a zoonotic disease response.

Disagreements and miscommunication between One Health partners have occurred and may be attributable to varied priorities, missions and lexicons. For example, diagnostic samples may be withheld by animal producers concerned about movement restrictions because of an uncertain diagnosis, public health authority action or public misperception (Anon, 2009). Results of diagnostic assays may not be available because of informatics issues or legal restrictions on laboratories (Crom, 2002), and researchers or governments may delay sharing isolates or agent sequence information for other reasons (Anon, 2006a). Further, consensus among states on disease surveillance or response plans may be difficult to achieve because of differing animal industry concentration or production methods. Federal-to-federal or federal-to-state assistance may be hampered by confusion on authorities or delays in funding (GAO, 2011). Nations will differ on their perception of risk, particularly concerning a new isolation or outbreak. However, today, the outline of how various partners would contribute in the response to a major animal or zoonotic outbreak is better known than a decade ago.

The prevention, preparedness, response, recovery continuum

The actions APHIS and its partners take are part of the Prevention, Preparedness, Response and Recovery (PPRR) continuum. However, the actions and phases are interrelated, and each would play a role in the response. For example, prevention measures may be elevated during a response to limit further entry, and tools prepared would be used in the response. The considerations for recovery will affect response choice.

Prevention

Prevention is the height of mitigation, another term used in some emergency management cycles. APHIS–VS prevention consists largely of import controls, permitting, intelligence and biosecurity. The animal diseases and controls in a country impact its ability to export animals and animal products. One way APHIS–VS addresses risks is the requirement for permits to import animals and animal products. International guidelines also set parameters for safe trade in animals and animal products. The OIE lists of 71 reportable diseases (OIE, 2011a) and transparent reporting of the presence of those diseases (OIE, 2009b, 2010) are intended to protect countries from introducing pathogens through trade. The World Trade Organization's Sanitary and Phytosanitary Agreement names OIE as the relevant organization for animal health (OIE, 2011b), meaning trade restrictions based on disease presence and absence are expected. The risk factors are similar for many known and emerging animal diseases (Gibbs and Anderson, 2009). Therefore, entry restrictions focused on a single known pathogen may prevent entry of other known or unknown agents. For example, the list of countries with swine import restrictions based on CSF includes those with Nipah (APHIS, 2011c).

Early warning systems assist countries with disease situations and prevent unintentional or intentional spread of the diseases to other countries. An example of early warning systems is EMPRES-i, the information system of the FAO's Emergency Prevention Programme for Transboundary Animal Diseases [Food and Agriculture Organization (FAO), 2011]. Other examples are the Global Early Warning System (GLEWS) (FAO, OIE, World Health Organization, 2011) for major animal diseases as well as information integration systems, such as the National Biosurveillance Information System (NBIS) (Anon, 2007), Argus, and the Biological Indication and Warning Analytic Community (BIWAC) (CDC, 2008).

Interdiction of biological agents is made more difficult by lack of 'stand-off technology', presence of background flora, latent periods of infection and amplification after introduction. However, multiple mechanisms have been implemented for safeguarding from unannounced or unknown risks. Inspections at ports, testing of animals, treatment of product, certification and quarantine in the country of origin and the United States guard against the importation of known and unknown diseases. Education of travellers and animal owners on topics such as biosecurity practices helps prevent introduction of exotic animal diseases via animals, animal products, or fomites. Inspection and permitting of select agent laboratories in the United States and permitting of select agent movement and possession forestall accidental or deliberate release from laboratories.

Preparedness

In addition to prevention, the animal health community and its One Health partners conduct preparedness activities. Preparedness builds and sustains capabilities through planning, organizing, equipping, training and conducting exercises. APHIS–VS uses the national core capabilities list, modified from the earlier target capabilities list, to prepare [Emergency Management Agency (FEMA), 2011a].

The federal interagency emergency community has developed 15 all-hazards planning scenarios (the National Planning Scenarios) for use in national, federal, state and local homeland security preparedness activities. Three of the scenarios concern zoonotic disease agents (anthrax, plague and influenza). Two scenarios are especially germane to this discussion: Scenario 14: Biological Attack – Foreign Animal Disease (Foot and Mouth Disease) and Scenario 3: Biological Disease Outbreak – Pandemic Influenza (FEMA, 2009). The priority the animal health community places on FMD and AI correlates with the two scenarios, and many plans and exercises (government and private) that can be extrapolated to other diseases have been done on these two diseases. However, the third highest priority disease on the NVS disease list is RVF (APHIS, 2009a), an arthropod vector-borne disease that would present additional issues for responders. A multiagency, internationally attended tabletop and laboratory tactical exercise was conducted for this disease in Florida in 2008 (Christy, 2009).

Preparedness also includes situational awareness. Knowledge of the threats is needed to prepare appropriate countermeasures, for example, monitoring the evolution of a virus to assess the need to stockpile vaccine of a different seed or surveillance in wild waterfowl to monitor prevalent AI subtypes (Hinshaw et al., 1985). Situational awareness also includes knowledge of the capabilities and priorities of other entities including the private sector. Awareness of the tools others are using or that may soon become available may allow priority acquisition of the tools (e.g. vaccine approval and stockpiling) and planning for their use (Agricultural Research Service, 2011).

Research is another important preparedness activity. The full range of research is needed for effective response, from identification of a pathogen and its antigens, elicited immune response or ecology to field application and commercialization of technologies (Murphy, 1998). USDA performs its own research, funds research performed by others (e.g. universities) and leverages the results of work by a wide variety of others (international, other U.S. government and commercial concerns such as vaccine companies).

Mandated in Homeland Security Presidential Directive (HSPD) 9 (GAO, 2011), NVS obtains and stores countermeasures against the most damaging animal diseases. NVS is charged with delivering countermeasures to states, tribes and territories within 24 h. The countermeasures include vaccines, personal protective equipment and antivirals, animal handling and communications equipment, the means for depopulation, disposal, and disinfection, and response services. The NVS is charged in HSPD-9 to leverage where appropriate the mechanisms and infrastructure for the HHS Strategic National Stockpile (SNS). Vaccine may be stockpiled or contracted (APHIS, 2009a).

Similar to the SNS, many of the biologics countermeasures are specific to the agent and in some cases serotype (the 'one bug – one drug' approach), an issue identified for more recent public health research and development strategies (National Institute of Allergy and Infectious Diseases, 2007). A fundamental difference between the NVS and the SNS is that the SNS is an integral part of a complete public health emergency medical countermeasure enterprise (PHEMCE) as established in the Pandemic and All-Hazards Preparedness Act (Anon, 2006b). The PHEMCE includes the Biomedical Advanced Research and Development Authority, specifically charged with bridging the 'valley of death', the gap between research and application. Various initiatives attempt to address the gap for veterinary countermeasures, including DHS funding of specific FAD vaccine research and commercialization projects, and evaluating or contracting for supply of vaccine from countries where the FAD is endemic.

Depopulation and disposal using conventional methods has been determined to be inconsistent with animal health emergency needs (Giovachino et al., 2007). Mass depopulation methods continue to be developed that are rapid, as humane as possible, scalable and compatible with appropriate disposal methods. Examples include poultry carbon dioxide/foam, swine electrocution and cattle pithing. The challenge of carcass disposal for mass mortality means multiple methods will likely be used in an emergency (National Agiculture Biosecurity Center Consortium, 2004; APHIS, 2012). Methods that protect groundwater and air quality, as well as being biosecure, economical and practical (e.g. rendering followed by disinfection, composting in some situations and gasification), also continue to be developed and validated.

EPA approves disinfectant claims on labels or in product instructions. For some diseases (e.g. influenza), many registered products are available for human and animal applications. In other cases (e.g. RVF and African swine fever), products are not registered or are not registered for animal housing or equipment use. Studies validating common chemicals (e.g. citric acid) for bulk use in exotic animal disease emergencies continue (Krug et al., 2011). Extrapolation from data using known agents may be necessary in an outbreak of a new or emerging agent.

Simulation models of disease spread (Harvey et al., 2007; Kobayashi et al., 2007) and other models (Hartley et al., 2011) can assist with planning and decision-making on intervention options, including providing the economic impacts of each. It can also help with resource estimation (e.g. how many vaccine doses, diagnostic field teams and diagnostic tests will be needed). Tabletop and full-scale exercises, which often use models, help uncover capability gaps, identify conflicts, etc., so they can be addressed before the real event occurs. National level exercises are done at a high level to provide awareness to senior officials and identify authorities to be used in the emergency. The Homeland Security Exercise and Evaluation Program (FEMA, 2011b) is a widely used national standard exercise programme that provides methodology and terminology for exercise design, development, conduct, evaluation and improvement planning. Training and credentialing prepares personnel for specific roles in responses and assures the organization and its partners of personnel skill levels and readiness. Resource ordering and dispatching systems provide for rapid and scalable deployment of personnel and materiel.

Tracing the index case movements and contacts backward is a key to response. Tracing back helps control new cases infected by the index case contacts and may allow identification of the source of the infection. In the past, specific animal disease control programmes provided components of a traceability programme, for example, animal identification and documentation on transport origin and destination. However, it was not comprehensive, and as the prevalence of the targeted disease decreased, the identified proportion of the population was reduced. The inability to trace many of the cohorts of the 2003 BSE index case and more recent difficulties in bovine tuberculosis traces (Breitmeyer et al., 2010) have highlighted the gaps in the current U.S. animal traceability system and practices (GAO, 2007). Under the current proposed rule Traceability for Livestock Moving Interstate (APHIS, 2011d), livestock (including poultry) moving inter-state would be required to be officially identified and accompanied by an inter-state certificate of veterinary inspection (or other documentation).

The threat of animal disease outbreaks and the lessons learned from past outbreaks in the United States and other countries led to the development of the Foreign Animal Disease Preparedness and Response Plan or 'FAD PReP' (APHIS, 2010a). The plan was developed in a public–private–academic partnership and is a comprehensive U.S. preparedness and response strategy for zoonotic and non-zoonotic animal health threats. The strategy is provided and explained in an integrated series of different types of documents.

The documents include strategic plans and concepts of operations such as the APHIS Framework for Foreign Animal Disease Preparedness and Response; National Animal Health Emergency Management System guidelines, such as personal protective equipment, biosecurity and vaccination; industry manuals; disease response plans (e.g. HPAI Response Plan Redbook); and ready reference guides. Also included are critical activity standard operating procedures on topics such as disposal, depopulation and disinfection; outbreak response tools such as case definitions; NVS countermeasures; State and Tribal Plans/resources; industry, academic and extension plans and resources; and APHIS emergency management documents. A recently added category of documents is continuity of business plans, such as the Secure Milk Supply and Secure Egg Supply plans. The large number and types of documents may now challenge the end user's ability to assimilate and rapidly employ the tools, which has necessitated the development of aids (APHIS, 2011a, 2012).

Response

In the response to a significant zoonotic disease event, specific people, authorities, institutions, networks, systems and tools would be mobilized and applied according to the exercised plans, policies and procedures previously described. A key to effective response is early detection. The U.S. infrastructure employs both passive and active surveillance to detect disease.

Passive surveillance depends on quick recognition by owners and veterinary practitioners and the systems supporting them. Accredited veterinarians 'must report immediately to the (federal) Area Veterinarian in Charge and State Animal Health Official all diagnosed or suspected cases of a communicable disease for which APHIS has a control or eradication programme and for all diagnosed or suspected cases of any animal disease not known to exist in the United States' (Anon, 2010). All practitioners should be trained to recognize such diseases. Veterinary colleges include the web-based course Emerging and Exotic Diseases of Animals in their curricula, and it is now available for continuing education credits for veterinarians and veterinary technicians (Center for Food Safety and Public Health, 2011). Systems to capture and act on practitioner concerns include the Ag/Livestock Incident Response Team, an example of state support for private practitioner investigation of unusual mortalities (Ishmael, 2009) and notification systems such as the Maryland One Health Bulletin (Maryland Department of Agriculture, 2011). Practitioner submissions to veterinary diagnostic laboratories cognizant of state reportable disease lists are an important part of animal disease surveillance.

Active surveillance is conducted for specific diseases such as tuberculosis, scrapie, pseudorabies and AI. Sampling may be conducted on live healthy animals (random sampling on flock/herd), on sentinels, on animals with clinical signs or at slaughter (including targeting based on clinical signs, lesions or cull status, Crom, 2002). Surveillance can be assisted by risk assessment and pathway analysis (Bjornsen and Howe, 2007; Kasari et al., 2008) and might be enhanced by environmental sampling or syndromic surveillance. In the National Animal Health Reporting System, participating State animal health officials voluntarily report monthly on the occurrence of confirmed OIE-reportable diseases in U.S. livestock, poultry and aquaculture species.

The US animal disease surveillance system has been criticized as being 'piecemeal, passive and disease specific…. neither designed to nor incidentally able to detect emerging diseases, or natural or introduced outbreaks outside of targeted diseases' (Wurtz and Popovich, 2002). Traditional disease reporting is cited as generally 'slow and incomplete, and, therefore not well suited to provide early detection and warning of a disease outbreak', and the voluntary nature of reporting was noted as limiting the federal government's ability to ensure accuracy, completeness or timely reporting (GAO, 2010). The need for increased integration of animal and human health surveillance has also been highlighted (Rabinowitz et al., 2009; GAO, 2010). An APHIS–VS initiative on design of comprehensive, integrated species surveillance has been launched to address some of the concerns (APHIS, 2011a).

The National Animal Health Laboratory Network (NAHLN) supports early detection through agent-specific, standardized, rapid FAD assays on routine (endemic disease) diagnostic submissions and suspect cases, and potentially through investigation of trends in undiagnosed cases (APHIS, 2011e). Figure 1 shows the geographic spread and specialization of the NAHLN, including APHIS' National Veterinary Services Laboratories (NVSL) as the confirmatory and reference laboratories. Multiplex assays (Hindson et al., 2007) differentiating the exotic agent from endemics with similar clinical signs might be used to advantage in routine submission testing, if sensitivity were sufficient. Once a detection (particularly of a new agent or strain of agent) is made, analysis or evaluation may be needed before action. The Tool for the Assessment of Intervention Options (APHIS, 2010b) has recently been employed for specific decision-making-for example, to decide depopulation versus test-and-remove approaches for affected herds.

The combination of multiple NAHLN laboratories and standardized high throughput assays and equipment allows scale-up of laboratory testing for response and recovery. An ongoing NAHLN project aims to standardize data (using international data standards), improve data quality and speed laboratory results reporting through electronic data transfer (APHIS, 2011e). NAHLN coordinates on assays and protocols with the food, public health (Laboratory Response Network) and environmental national laboratory networks, including via the integrated

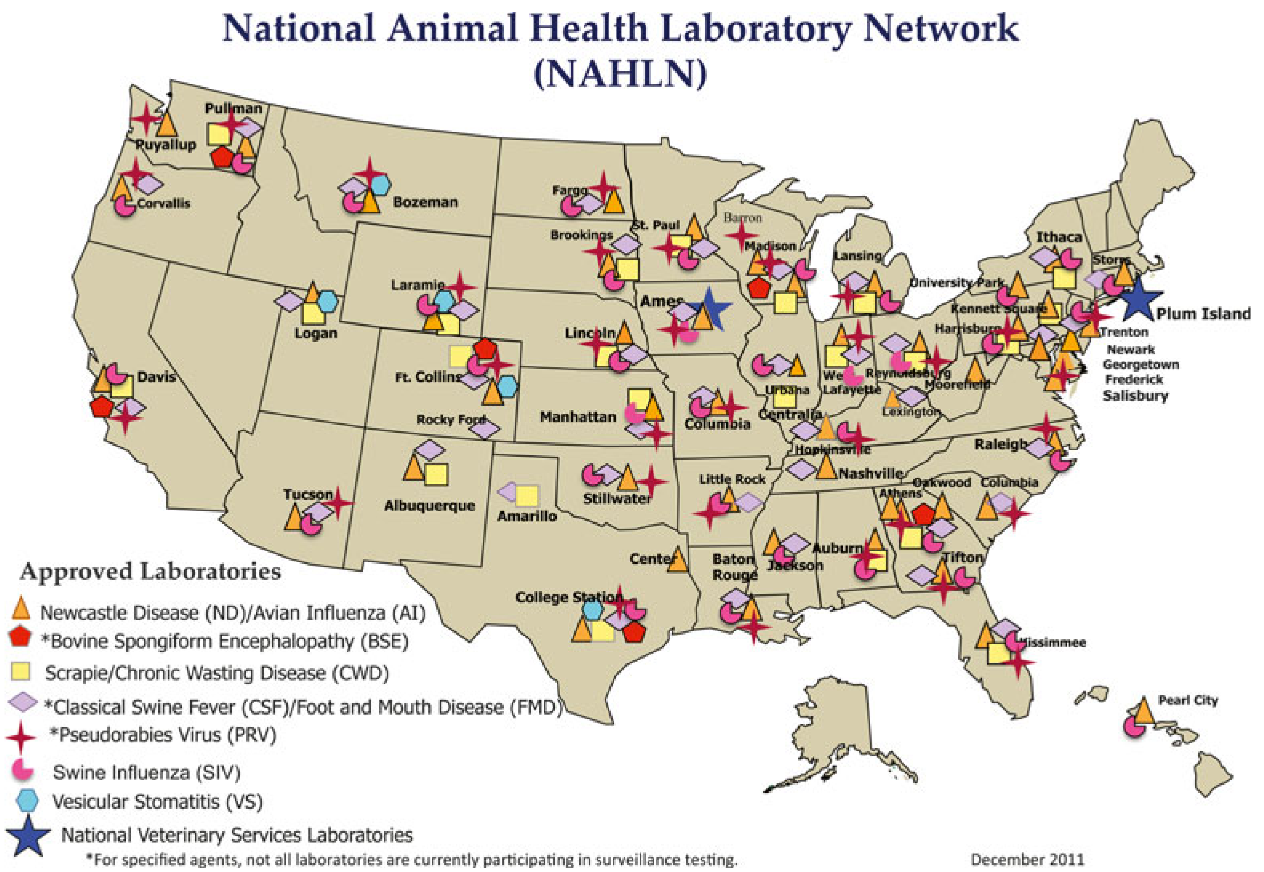

Fig. 1. The locations and capabilities of National Animal Health Laboratory Network laboratories. Reproduced from APHIS, 2011e.

consortium of laboratory networks. The diagnostic assays used must not only be sensitive for early detection but also be specific. False-positive results or reporting is a particular concern in animal health because of their impact on trade. Export of live animals and animal products is a large part of some animal industries' market and their economic viability (Economic Research Service, 2011). Restrictions on exports can be imposed rapidly, and return to normal status can be delayed, even for false-positive results.

Specially trained (federal, state or military) Foreign Animal Disease Diagnosticians, Veterinary Services Assessment Teams and Incident Management Teams would be part of the early or limited response. They might be assisted by local law enforcement and other animal health officials. The scale-up in response could involve VS field personnel, other APHIS personnel (APHIS personnel are internally credentialed for a response position) and other federal or state personnel (including federal-to-federal support under the NIMS concept). It could also include private veterinary and animal health professionals through the National Animal Health Emergency Reserve Corps (APHIS, 2011f) or State/local equivalents, accredited veterinarians (e.g. for movement control) and for some tasks (e.g. depopulation) trained and medically qualified personnel contracted by the NVS.

The authorities applied would be a combination of those concerning federal animal health (e.g. interstate commerce); state animal health (quarantine); federal, state and local public health; and likely, law enforcement (including possibly federal, state or local) (Knowles et al., 2005). Funding for initial action could be available from the APHIS Administrator's Contingency funds (an appropriated line item). In connection with an emergency, the AHPA authorizes the Secretary of Agriculture to transfer within USDA 'such funds that the Secretary deems necessary for the arrest, control, eradication or prevention of the spread of a pest or disease of livestock' (Anon, 2002b). Commodity Credit Corporation funds are held by the Farm Service Agency, but in an animal health emergency may be transferred to APHIS for further distribution in a state if the finding is made that state actions are inadequate to control the pest or disease. The Secretary of Agriculture may declare an agricultural emergency or an extraordinary agricultural emergency when additional federal assistance is needed to protect U.S. agriculture.

The National Response Framework (FEMA, 2008a) provides the structure and mechanisms for national level policy for incident management. NIMS provides a systematic, proactive approach to guide departments and agencies at all levels of government, non-governmental organizations and the private sector for PPRR and mitigation of incidents. It incorporates the ICS, MACS and public information, and includes Emergency Support Functions (ESF), which facilitate federal-to-state and federal-to-federal support. ESF-11, Agriculture and Natural Resources (FEMA, 2008b) includes agricultural issues (APHIS lead), food (FSIS lead) and pet rescue (APHIS lead, in coordination with HHS and ESF-8, Public Health and Medical Services). It includes implementing an integrated Federal, State, tribal and local response to an outbreak of a highly contagious or economically devastating animal/zoonotic disease, or an outbreak of a harmful or economically significant plant pest or disease. The ICS is a management system designed to integrate a combination of facilities, equipment, personnel, procedures and communication operating within a common organizational structure, for efficient domestic incident management. It is scalable and allows individuals and organizations of multiple disciplines to work together. APHIS has adopted NIMS and ICS organizational structures and processes (including a unified federal/state command) to manage emergency responses.

In a response, the challenges include rapidly linking information concerning animal identification, location and movement; epidemiology, modelling and intelligence; pre-event surveillance information, diagnostic sampling and test results; and current versus projected personnel and other resources (APHIS, 2009b). Current systems join many of these data streams (APHIS, 2003), but in an event, the needed data may exist in multiple systems held by various agencies and entities. The situation would be more complex in a zoonotic event because of human, human–animal and possibly other (wildlife, environmental) interactions. 'Dashboard' (user interface) approaches have been proposed to address this problem (National Center for Foreign Animal and Zoonotic Disease Defense, 2011).

Many response strategies are needed to contain, control or eradicate an FAD outbreak (APHIS, 2010a). The strategies include epidemiological investigation and FAD tracing, as well as biosecurity to reduce spread and surveillance to determine the extent of the outbreak. They also include zoning, quarantine, vector control and movement control, although this may cause welfare concerns because of the animals continuing to grow, causing overcrowding. Depopulation and destruction of animal products with indemnity, proper sanitary disposal, cleaning and disinfection are other strategies as are public awareness campaigns, and continuity of business and emergency vaccination (prophylactic vaccination could be considered a mitigation measure). An OIE conference on the control of animal disease by vaccination was held in 2004, noting 'emerging and re-emerging infectious animal diseases and zoonoses have often been controlled by implementing a policy of mass slaughter. However, this approach to disease control poses considerable ethical, technical, ecological and economic problems, and there is a need for alternative control strategies' (Schudel and Lombard, 2007). An illustration of a classic zoning approach (including stamping out and vaccination) that could be used is shown in Fig. 2. Animal and disease movement data and continuity of business measures might dramatically alter such an approach. Safe movement, preservation of genetics, humane considerations and food security are top priorities in the eradication or control of the animal disease.

Emergency vaccination requires vaccinated animal traceability and use of the 'differentiate infected and vaccinated animals' (DIVA) strategy (vaccine and diagnostic) for movement between zones, interstate commerce and international trade. It is particularly important to the recovery step 'proof of freedom with vaccination.' Potential emergency vaccination strategies include stamp-out without vaccination, stamp-out with vaccination to kill/slaughter, stamp-out with vaccination to live, or live with the disease and vaccinate. Factors influencing the decision to vaccinate to live include availability of suitable vaccine, susceptible animal population density, distribution of outbreaks, rapidity of spread, knowledge of outbreak origin, public acceptance of depopulation, difficulty of

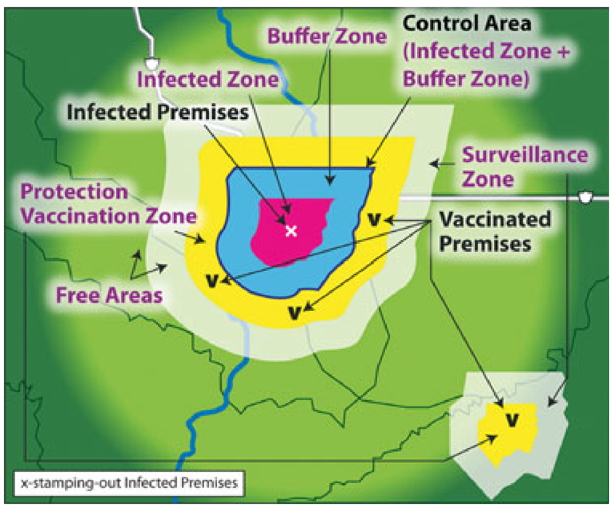

Fig. 2. Examples of Zones and Areas in Relation to Stamping-Out Modified with Emergency Vaccination to Live (All Infected Premises would be Depopulated). Reproduced from APHIS, 2010a.

depopulation and disposal, stakeholders' and trading partners' acceptance of regionalization, and the public health impact of vaccination.

The topic of suitable vaccine availability is multi-faceted and includes the issue of strain matching. Strain matching includes the ability to rapidly insert genetic information from the field isolate into a vaccine or vaccine production vector or adapt the field virus to production (Forde, 2005; Defense Advanced Research Projects Agency, 2006; Matthews, 2006; Rodriguez and Grubman, 2009; Middelberg et al., 2011). Other issues to consider in availability of vaccine include importing vaccine from a country where the disease is endemic or an emergency response is ongoing; stockpiling and manufacturing scale-up; and prioritizing between nations and zones or species within a nation. Many of the availability issues or practices relate to or would result in delays in vaccine delivery to targeted populations.

Other considerations when deciding on vaccination include the effect of vaccination on public exposure, such as the impact on the shedding of the agent as well as on the duration and distribution of the outbreak. In addition, vaccination suppression of clinical signs results in a need for increased laboratory testing versus observational diagnosis. The combination of reduced clinical detection and the concern that the response to the marker antigen will be reduced during infection (resulting in a false-negative DIVA test, Alexandersen et al., 2003) may result in import restrictions for the nation or large areas (e.g. states) using vaccination. Further, the perception of meat from animals potentially exposed or even vaccinated can be negative (Kahn et al., 2002; Giuseppe et al., 2008), impacting domestic markets.

Recovery

The recovery phase of emergency management includes actions taken to return to the pre-event state or better (steps may be taken to strengthen prevention and mitigation). A common description is repair, rebuilding and re-employment after the event. In the case of a large disease event, recovery may start during the response. For example, regionalizing and performing additional surveillance to designate large geographic areas as uninfected may restore international trade of live animals and animal products from the free areas. Other recovery activities might include continuity of business actions (e.g. Secure Milk Supply, Iowa State University et al., 2011) that could allow product movement quickly after initial stoppage, slaughter of vaccinated animals to return the population to seronegative status (in one of the vaccination scenarios described) and public messaging to restore public confidence in the food supply.

The example of novel influenza A viruses in swine and humans

A succession of events (2005-recent) illustrates the characteristics of zoonotic disease preparedness and response in the United States and the need and benefit of a One Health approach to address these issues at the animal–human–environment interface. Between December 2005 and January 2009, 12 cases (in nine states) of human infection with influenza viruses circulating in swine were reported. It represented an increase in detections over the one to two per year previously noted (Myers et al., 2007) and included nine cases since novel influenza A virus infections in humans became notifiable in June 2007. The 12 cases included five in people with direct exposure to swine and six in people near pigs (Ginsberg et al., 2009). Possible person-to-person transmission was noted, but no sustained human transmission occurred, and all recovered (Shinde et al., 2009).

In July 2008, APHIS and ARS entered into cooperative agreements with the CDC to initiate a swine influenza (SIV) surveillance pilot project. The project was designed to 'study the incidence and distribution of SIV subtypes in swine populations, look for novel influenza isolates, and collect data and isolates to better understand the epidemiology and ecology of SIV in swine and documented human SIV infections' (APHIS, 2010b). An algorithm for notification and communication between human and animal health authorities when novel influenza A viruses were identified in humans was developed.

When the human pandemic influenza outbreak occurred in April 2009, CDC quickly shared human H1N1 virus isolates with USDA. It enabled ARS and NVSL to rapidly develop and deploy to the NAHLN an A(H1N1)pdm09-specific diagnostic polymerase chain reaction (PCR) assay. Diagnostic laboratory testing algorithms were designed that allowed differentiation of endemic swine influenza H1N1 genotypes and other swine influenza subtypes from the pandemic H1N1 for expanded surveillance. ARS used the human isolates to study the virus in pigs, providing important information about clinical characteristics of the virus in swine, the safety of pork from infected or recovered pigs and preliminary data on the efficacy of current swine influenza vaccines for the pandemic subtype. The APHIS Center for Veterinary Biologics provided pre-tested seed stock virus to swine vaccine manufacturers to facilitate the rapid deployment of strain-specific swine vaccines (APHIS, 2009c).

The surveillance pilot was expanded and then modified into the national SIV surveillance programme (APHIS, 2010c). It was designed to (i) monitor genetic evolution of SIV to better understand endemic and emerging influenza virus ecology; (ii) make available SIV isolates for research and to establish an objective database for genetic analysis of these isolates and related information; and (iii) select proper isolates for the development of relevant diagnostic reagents, for updating diagnostic assays and for vaccine seed stocks. The voluntary surveillance system samples swine from any of three categories: (i) case-compatible swine accessions submitted to veterinary diagnostic laboratories (this surveillance will cover on-farm swine populations exhibiting influenza-like illness (ILI); (ii) groups of swine exhibiting ILI at first points of concentration or commingling events, such as auctions, markets, fairs or other swine exhibition events; and (iii) swine populations epidemiologically linked to a confirmed isolation of SIV in a human. The haemagglutinin, neuraminidase and matrix gene sequences of ~150 SIV isolates have been determined and submitted to GenBank (Richards et al., 2012).

Since the pandemic, additional human cases of variant influenza virus infections have occurred, including infections with variant H1N1, H3N2 and more recently with an H3N2 containing the A(H1N1)pdm09 virus M gene segment (Nalluswami et al., 2011; Richards et al., 2012). All state public health laboratories have the capacity to test respiratory specimens for influenza viruses with sensitive and specific assays that can detect human and non-human influenza A viruses. They also have the capacity to subtype currently circulating human influenza A H1, H3 and avian H5 (Asian lineage) viruses and the vH3N2 virus specifically (CDC, 2010; Richards et al., 2012). If the virus is an un-subtypable influenza A or inconclusive using those tests, it is forwarded to CDC for testing and confirmation.

CDC laboratory confirmation of these sporadic human cases of variant influenza virus infections results in prompt CDC and USDA notifications as per the established algorithms. This is followed by discussions and joint investigation between CDC, USDA, and state and local public and animal health officials to ascertain whether these viruses are transmitted among humans and to limit further exposure of humans to infected animals, if infected animals are identified.

Conclusion

The animal health community continues to prepare for exotic and emerging zoonotic diseases. Many of the animal disease PPRR methods, authorities, experience, and partnerships can be applied to advantage in a zoonotic disease outbreak. Continued improvements in the process, resources and tools are needed to address this threat. For an effective zoonotic disease response, improvements are also needed to coordinate and integrate plans, policies and procedures within and between the public, animal, wildlife and environmental health communities. Being informed on the capacities and capabilities, methods, partners' jurisdiction, authorities, roles and responsibilities, as well as stakeholder and public impacts of each community, will contribute to that coordination and integration. The situation has improved with the pandemic flu preparedness and novel influenza A surveillance/response, but considering the frequency of zoonoses emergence and the acknowledged threat, more needs to be done.

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Conflicts of interest

No conflicts of interest apply.

References

Agricultural Research Service, 2011. National veterinary stockpile foot and mouth disease countermeasure working group. Available at: http://www.ars.usda.gov/research/projects/projects.htm?accn_no=419983 (accessed October 18, 2011).

Alexandersen, A., Z. Zhang, A. I. Donaldson, and A. J. M. Garland, 2003: The pathogenesis and diagnosis of foot-and-mouth disease. *J. Comp. Path.* 129, 1–36.

American Veterinary Medical Association, One Health Initiative Task Force, 2008. One health: a new professional imperative. Available at: http://www.avma.org/onehealth/onehealth_final.pdf (accessed November 6, 2011).

Amezcua, M. D. R., D. L. Pearl, R. M. Friendship, and W. B. McNab, 2010: Evaluation of a veterinary-based syndromic surveillance system implemented for swine. *Can. J. Vet. Res.* 74, 241–251.

Animal and Plant Health Inspection Service (APHIS), 2003. EMRS manual for routine FAD/EDI investigations. Available at: http://www.aphis.usda.gov/vs/ep/trainingCD/EMRS_for_Routine_FAD_Investigations.htm (accessed November 1, 2011).

Anon, 2002a. Interstate movement of diseased animals and poultry generally prohibited. 9 CFR 71.3 (b).

Anon, 2002b. The Animal Health Protection Act. P.L. 107-171, Title X, Subtitle E; 7 U.S.C. 8301 et seq.

Anon, 2005. Virus-Serum-Toxin Act or VST Act. P.L. 430 of 1913, as amended; 21 U.S.C. 151-159 et seq.
Anon, 2006a: Action stations. *Nature* 441, 1028.
Anon, 2006b. Pandemic and All-Hazards Preparedness Act. P.L. 109-417, 120 STAT. 2831.
Anon, 2007. National Biosurveillance Integration Center; 6 U.S.C. 195b.
Anon, 2009. Fear over H1N1 detection brings down swine disease samples. DVM Newsmagazine, September 25, 2009. Available at: http://veterinarynews.dvm360.com/dvm/Veterinary+news/Fear-over-H1N1-detection-brings-down-swine-disease/ArticleStandard/Article/detail/629360?contextCategoryId=378 (accessed February 19, 2012).
Anon, 2010. Standards for accredited veterinarian duties. 9 CFR 161.3.
APHIS, 2009a. National veterinary stockpile planning guide for federal, state, and local authorities, version 2. Available at: http://www.aphis.usda.gov/animal_health/emergency_management/nvs.shtml (accessed November 1, 2011).
APHIS, 2009b. Veterinary services information technology roadmap: a new direction, paving the way for the future. Available at: http://www.aphis.usda.gov/animal_health/vs_ocio/downloads/vs_it_roadmap.pdf (accessed November 1, 2011).
APHIS, 2009c. News release: USDA issues conditional license for pandemic H1N1 vaccine for swine. Available at: http://www.aphis.usda.gov/newsroom/content/2009/12/h1n1_vaccine.shtml (accessed November 1, 2011).
APHIS, 2010a. FAD PReP framework. Available at: https://fad.prep.lmi.org (accessed October 26, 2011).
APHIS, 2010b. 2009 Animal health report. Available at: http://www.aphis.usda.gov/animal_health/animal_health_report/index_2009.shtml (accessed November 1, 2011).
APHIS, 2010c. Influenza surveillance in swine procedures manual. Available at: http://www.aphis.usda.gov/animal_health/animal_dis_spec/swine/siv_surv_manual.shtml (accessed November 2, 2011).
APHIS, 2011a. Veterinary services: a new perspective. Available at: http://www.aphis.usda.gov/about_aphis/programs_offices/veterinary_services/downloads/vs2015/vs_new_perspective.pdf (accessed September 11, 2011).
APHIS, 2011b. National veterinary stockpile and Navajo nation conduct successful logistics exercise. Available at: http://www.aphis.usda.gov/animal_health/emergency_management/downloads/nvs_nn_fse_article.pdf (accessed November 1, 2011).
APHIS, 2011c. Animal and animal product import: classical swine fever information. Available at: http://www.aphis.usda.gov/import_export/animals/animal_import/animal_imports_csf.shtml (accessed November 1, 2011).
APHIS, 2011d: Traceability for livestock moving interstate. *76 Federal Register* 155, 50082–50110.
APHIS, 2011e. National animal health laboratory network. Available at: http://www.aphis.usda.gov/animal_health/nahln/ (accessed December 1, 2011).
APHIS, 2011f. NAHERC strength as of July 2011. *NAHERC Quarterly* 1:3. Available at: http://www.aphis.usda.gov/animal_health/emergency_management/downloads/volume_1_issue_4.pdf (accessed November 7, 2011).
APHIS, 2012. Emergency management tools. Available at: http://www.aphis.usda.gov/emergency_response/tools/aphis_role_emergency_tools.shtml (accessed February 20, 2012).
APHIS, Center for Disease Control and Prevention (CDC), 2011. Select agents and toxins list. Available at: http://www.selectagents.gov/Select%20Agents%20and%20Toxins%20List.html (accessed October 12, 2011).
Barrette, R. W., S. A. Metwally, J. M. Rowland, L. Xu, S. R. Zaki, S. T. Nichol, P. E. Rollin, J. S. Towner, W.-J. Shieh, B. Batten, T. K. Sealy, C. Carrillo, K. E. Moran, A. J. Bracht, G. A. Mayr, M. Sirios-Cruz, D. P. Catbagan, E. A. Lautner, T. G. Ksiazek, W. R. White, and M. T. McIntosh, 2009: Discovery of swine as a host for the *Reston ebolavirus*. *Science* 325, 204. doi: 10.1126/science.1172705.
Bjornsen, M. A., and R., Howe, 2007. Pathways assessment mapping tool aids in risk analysis. NAHSS Outlook 2007(2). Available at: http://nsu.aphis.usda.gov/outlook/issue14_apr07/outlook_apr_2007_pamt.pdf (accessed October 17, 2011).
Breitmeyer, R., V. Velez, and A. Edmondson, 2010. Traceability: a California perspective (presentation). Available at: http://www.animalagriculture.org/Solutions/Proceedings/Annual%20Conference/2010/Animal%20ID/Breitmeyer,%20Richard.pdf (accessed February 17, 2012).
CDC, 2008. Engagement through Biosurveillance. CDC global health e-brief. Available at: http://www.cdc.gov/washington/EGlobalHealthEditions/eGlobalHealth0408.htm (accessed October 17, 2011).
CDC, 2010. Novel influenza A virus infections. Available at: http://www.cdc.gov/osels/ph_surveillance/nndss/casedef/novel_influenzaA.htm (accessed November 2, 2011).
CDC, 2011. Emergency preparedness and response. Bioterrorism Agents/Diseases. Available at: http://www.bt.cdc.gov/agent/agentlist-category.asp (accessed September 9, 2011).
Center for Food Safety and Public Health, 2011. Emerging and exotic diseases of animals. Available at: http://www.cfsph.iastate.edu/EEDA-Course/ (accessed November 1, 2011).
Christy, G., 2009. Florida State rift valley fever exercise and laboratory tactical exercise, report of the USAHA/AAVLD committee on animal emergency management. In Proceedings, 113th Annual Meeting, United States Animal Health Association, 2009. Richardson Printing, Kansas City, MO.
Crom, R. L., 2002: Veterinary surveillance for zoonotic diseases in the United States. In: Burroughs, T., S., Knobler, and J. Lederberg (eds), The Emergence of Zoonotic Diseases: Understanding the Impact on Animal and Human Health, pp. 90–98. National Acadamies Press, Washington, DC.
Day, M. J., L. L. Ballard, M. V. Duke, B. E. Scheffler, and L. Zsak, 2010: Metagenomic analysis of the turkey gut RNA

virus community. *Virol. J.* 7, 313. doi :10.1186/1743-422X-7-313.
Defense Advanced Research Projects Agency, 2006. Accelerated manufacturing of pharmaceuticals (AMP): solicitation number: BAA06-31. Available at: https://www.fbo.gov/index?tab=core&s=opportunity&mode=form&id=be83951ae201d2640b1928d64d7ca2a1 (accessed October 24, 2011).
Economic Research Service, 2011. Farm income and costs: farm business income. Available at: http://www.ers.usda.gov/Briefing/FarmIncome/businessincome.htm (accessed October 23, 2011).
Elvinger, F., and L., Becton, 2010. Report of the USAHA/AAVLD Committee on Animal Health Surveillance and Information Systems. Available at: http://portals5.gomembers.com/Portals/6/Reports/2010/report-ahis-2010.pdf (accessed November 2, 2011).
FAO, World Organization for Animal Health (OIE), World Health Organization, 2011. GLEWS global early warning system for major animal diseases, including zoonoses. Available at: http://www.glews.net/ (accessed October 31, 2011).
Federal Emergency Management Agency [FEMA], 2008a. National response framework. Available at: http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf (accessed November 2, 2011).
FEMA, 2008b. Emergency support function #11 – agriculture and natural resources annex. Available at: http://www.fema.gov/pdf/emergency/nrf/nrf-esf-11.pdf (accessed October 27, 2011).
FEMA, 2009. National planning scenarios. FEMA Fact Sheet, Available at: http://www.fema.gov/pdf/media/factsheets/2009/npd_natl_plan_scenario.pdf (accessed November 7, 2011).
FEMA, 2011a. National preparedness goal. Available at: http://www.fema.gov/pdf/prepared/npg.pdf (accessed October 17, 2011).
FEMA, 2011b. Homeland security exercise and evaluation program. Available at: https://hseep.dhs.gov/pages/1001_HSEEP7.aspx (accessed October 31, 2011).
Food and Agriculture Organization (FAO), 2011. EMPRES-i emergency prevention system. Available at: http://empres-i.fao.org/empres-i/home (accessed November 8, 2011).
Forde, G. M., 2005: Rapid-response vaccines – does DNA offer a solution? *Nature Biotech.* 23, 1059–1062.
GAO, 2010. Biosurveillance: Efforts to develop a national biosurveillance capability need a national strategy and a designated leader. Available at: http://www.gao.gov/products/GAO-10-645 (accessed February 17, 2012).
GAO, 2011. Homeland security: actions needed to improve response to potential terrorist attacks and natural disasters affecting food and agriculture (GAO-11-652). Available at: http://www.gao.gov/Products/GAO-11-652 (accessed November 6, 2011).
Gibbs, E. P. J., and T. C. Anderson, 2009: 'One World – One Health' and the global challenge of epidemic diseases of viral aetiology. *Vet. Ital.* 45, 35–44.
Ginsberg, M., A. Maroufi, G. Dunne, D. R. Sunega, J. Giessick, P. McVay, K. Lopez, P. Kriner, K. Lopez, S. Munday, K. Harriman, B. Sun, G. Chavez, D. Hatch, R. Schechter, D. Vugia, J. Louie, W. Chung, N. Pascoe, S. Penfield, J. Zoretic, V. Fonseca, P. Blair, D. Faix, J. Tueller, T. Gomez, F. Averhoff, F. Alavrado-Ramy, S. Waterman, J. Neatherlin, L. Finelli, S. Jain, L. Brammer, J. Bresee, C. Bridges, S. Doshi, R. Donis, R. Garten, J. Katz, S. Klimov, D. Jernigan, S. Lindstrom, B. Shu, T. Uyeki, X. Xu, and N. Cox, 2009: Swine Influenza A (H1N1) Infection in Two Children – Southern California, March–April 2009. *MMWR Weekly* 58, 400–402.
Giovachino, M., R. Speers, D. Morgan, D. Catarious, and E. Myrus, 2007. Operation Palo Duro: policy and decision-making in response to an FMD outbreak. (IPR) 12285. Available at: http://www.tahc.state.tx.us/emergency/May2007_OperationPaloDuro.pdf (accessed February 22, 2012).
Giuseppe, G. D., R. Abbate, L. Albano, P. Marinelli, and I. F. Agelillo, 2008: A survey of knowledge, attitudes and practices towards avian influenza in an adult population of Italy. *BMC Infect. Dis.*, 8, 36. doi:10.1186/1471-2334-8-36.
Government Accountability Office (GAO), 2007. National Animal Identification System: USDA needs to resolve several key implementation isssues to achieve rapid and effective disease traceback (GAO-07-592). Available at: http://www.gao.gov/products/GAO-07-592 (accessed February 17, 2012).
Gray, G. C., T. McCarthy, A. W. Capuano, S. F. Setterquist, M. C. Alavanja, and C. F. Lynch, 2008: Evidence for avian influenza A infections among Iowa's agricultural workers. *Influenza Other Respir. Viruses* 2, 61–69.
Hartley, D. M., J. L. Rinderknecht, T. L. Nipp, N. P. Clarke, G. D. Snowder, and National Center for Foreign Animal and Zoonotic Disease Defense Advisory Group, 2011: Potential effects of Rift Valley fever in the United States. *Emerg. Infect. Dis.* 17, 8. Available at: http://www.cdc.gov/EID/content/17/8/101088.htm (accessed November 1, 2011).
Harvey, N., A. Reeves, M. A. Schoenbaum, F. J. Zagmutt-Vergara, C. Dubé, A. E. Hill, B. A. Corso, W. B. McNab, C. I. Cartwright, and M. D. Salman, 2007: The North American animal disease spread model: a simulation model to assist decision making in evaluating animal disease incursions. *Prev. Vet. Med.* 82, 176–197.
Hindson, B. J., B. R. Baker, L. F. Bentley Tammero, R. J. Lenhoff, P. Naraghi-Arani, E. A. Vitalis, R. R. Slezak, P. J. Hullinger, S. M. Reid, K. Ebert, N. P. Ferris, and D. P. King, 2007. Diagnostic evaluation of a multiplexed RT-PCR microsphere array assay for the detection of foot-and-mouth and look-alike disease viruses. doi: http://dx.doi.org/10.2172/922093. Lawrence Livermore National Laboratory - UCRL-TR-234981, pp, 1–55.
Hinshaw, V. S., J. M. Wood, R. G. Webster, R. Deibel, and B. Turner, 1985: Circulation of influenza viruses and paramyx-

oviruses in waterfowl originating from two different areas of North America. *Bull. World Health Org.* 63, 711–719.

Iowa State University, University of California Davis, and University of Minnesota. 2011, Secure milk supply. Available at: http://securemilksupply.org/partners.php (accessed October 31 2011).

Ishmael, W., 2009. When, not if, disaster strikes. Available at: http://beefmagazine.com/business/0601-arizona-livestock-incident-response-team/ (accessed October 23, 2011).

Ito, T., H. Goto, E. Yamamoto, H. Tanaka, M. Takeuchi, M. Kuwayama, Y. Kawaoka, and K. Otsuki, 2001: Generation of a highly pathogenic Avian Influenza A virus from an avirulent field isolate by passaging in chickens. *J. Virol.* 75, 4439–4443.

Kahn, S., D. W. Geale, P. R. Kitching, A. Bouffard, D. G. Allard, and J. R. Duncan, 2002: Vaccination against foot-and-mouth disease: the implications for Canada. *Can. Vet. J.* 43, 349–354.

Kahn, L. H., B. Kaplan, and J. H. Steele, 2007: Confronting zoonoses through closer collaboration between medicine and veterinary medicine (as 'one medicine'). *Vet. Ital.* 43, 5–19.

Kasari, T. R., D. A. Carr, T. V. Lynn, and J. T. Weaver, 2008: Evaluation of pathways for release of Rift Valley fever virus into domestic ruminant livestock, ruminant wildlife, and human populations in the continental United States. *J. Am. Vet. Med. Assoc.* 232, 514–529.

Knowles, T., J. Lane, G. Bayens, N. Speer, J. Jaax, D. Carter, and A. Bannister, 2005: Defining law enforcement's role in protecting American agriculture from agroterrorism. Available at: https://www.ncjrs.gov/pdffiles1/nij/grants/212280.pdf (accessed February 17, 2012).

Kobayashi, M., T. E. Carpenter, B. F. Dickey, and R. E. Howitt, 2007: A dynamic, optimal disease control model for foot-and-mouth disease: I. Model description. *Prev. Vet. Med.* 79, 257–273.

Krug, P. W., L. J. Lee, A. C. Eslami, C. R. Larson, and L. Rodriguez, 2011: Chemical disinfection of high-consequence transboundary animal disease viruses on nonporous surfaces. *Biologicals* 39, 231–235.

Lipkin, W. I., 2008: Pathogen discovery. *PLoS Pathog.* 4, e1000002. doi: 10.1371/journal.ppat.1000002.

Maryland Department of Agriculture, 2011: Zoonotic and other animal diseases of concern in Maryland. *Maryland One Health Bulletin* 1, 1.

Matthews, J. T., 2006: Egg-based production of influenza vaccine: 30 years of commercial experience. *The Bridge* 36, 17–24.

Mauer, W. A., and J. B. Kaneene, 2005: Integrated human-animal disease surveillance. *Emerg. Infect. Dis.* 11, 1490–1491.

Middelberg, A. P., T. Rivera-Hernandez, N. Wibowo, L. H. Lua, Y. Fan, G. Magor, C. Chang, Y. P. Chuan, M. F. Good, and M. R. Batzloff, 2011: A microbial platform for rapid and low-cost virus-like particle and capsomere vaccines. *Vaccine* 29, 7154–7162.

Murphy, F. A., 1998: Emerging zoonoses. *Emerg. Infect. Dis.* 4, 429–435.

Myers, K. P., C. W. Olsen, and G. C. Gray, 2007: Cases of swine influenza in humans: a review of the literature. *Clin. Infect. Dis.* 44, 1084–1088.

Nalluswami, K., A. Nambiar, P. Lurie, M. Moll, J. Lute, O. Simwale, E. Smith, L. Sundberg, B. Seiler, S. Swanson, N. Hanshaw, C. Shultz, E. Moore, S. Richards, M. Glazier, K. Masterson, L. Hensler, C. Miller, M. Justice, S. Epperson, L. Brammer, L. Finelli, S. Trock, M. Jhung, J. Bresee, S. Lindstrom, A. Klimov, D. Jernigan, N. Cox, and J. Miller, 2011: Swine-origin influenza A (H3N2) virus infection in two children – Indiana and Pennsylvania, July–August 2011. *MMWR* 60, 1213–1215.

National Agiculture Biosecurity Center Consortium, 2004. Carcass disposal: a comprehensive review. Available at: http://fss.k-state.edu/FeaturedContent/CarcassDisposal/CarcassDisposal.htm (accessed February 20, 2012).

National Center for Foreign Animal and Zoonotic Disease Defense, 2011. Information dashboard framework (IDF): fact sheet. Available at: http://fazd.tamu.edu/files/2010/05/FACT-SHEET-information-dashboards-9.2011.pdf (accessed November 2, 2011).

National Institute of Allergy and Infectious Disease, 2007. NIAID strategic plan for biodefense research, 2007 update. Available at: http://www.niaid.nih.gov/topics/BiodefenseRelated/Biodefense/Documents/biosp2007.pdf (accessed February 19, 2012).

OIE, 2009a. Event summary: 2009 pandemic A/H1N1 influenza, United States of America. Available at: http://web.oie.int/wahis/public.php?page=event_summary&reportid=8613 (accessed November 6, 2011).

OIE, 2009b. World animal health information Database (WAHID) – Version: 1.4. Available at: http://web.oie.int/wahis/public.php?page=home (accessed November 5, 2011).

OIE, 2010: Notification of diseases and epidemiological information. In: Thiermann, A., E. Bonbon, S. C. MacDiarmid, J. Caetano, A. Hassan and S. Hargreaves (ed.), Chapter 1.1 in Terrestrial Animal Health Code, pp. 1–3. World Organisation for Animal Health, Paris, France.

OIE, 2011a. OIE Listed Diseases. Available at: http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2011/ (accessed November 6, 2011).

OIE, 2011b. Notification of animal and human diseases: global legal basis. Available at: http://www.oie.int/fileadmin/Home/eng/Current_Scientific_Issues/docs/pdf/notification-EN.pdf (accessed October 16, 2011).

Rabinowitz, P., M. Scotch, and L. Conti, 2009: Human and animal sentinels for shared health risks. *Vet. Ital.* 45, 23–24.

Richards, S., M. Glazier, K. Masterson, M. Denton, C. Miller, C. Liebig, A. J. Root, C. Whitt, J. Freshwater, S. Ibrahim, D. Bixler, C. Clark, L. Haddy, Swine Influenza Virus Team, D. Jordan, M. Biggerstaff, S. Epperson, L. Brammer, L. Finelli, S. Trock, M. Jhung, J. Bresee, S. Lindstrom, A. Klimov, D. Jernigan, N. Cox, R. Radcliff, and T. Taylor, 2012: Update:

influenza A (H3N2)v transmission and guidelines – five states, 2011. *MMWR* 60, 1741–1744.
Rodriguez, L. L., and M. J. Grubman, 2009: Foot and mouth disease virus vaccines. *Vaccine* 27, D90–D94.
Schudel, A. A., and M. Lombard, 2007: Recommendations of the OIE international conference on the control of infectious animal diseases by vaccination, Buenos Aires, Argentina, 13 to 16 April 2004. *Rev. Sci. Tech.* 26, 519–521.
Shinde, V., C. B. Bridges, T. M. Uyeki, B. Shu, A. Balish, X. Xu, S. Lindstrom, L. V. Gubareva, V. Deyde, R. J. Garten, M. Harris, S. Gerber, S. Vagoski, F. Smith, N. Pascoe, K. Martin, D. Dufficy, K. Ritger, C. Conover, P. Quinlisk, A. Klimov, J. S. Bresee, and L. Finelli, 2009: Triple-reassortant swine influenza A (H1) in humans in the United States, 2005–2009. *N. Engl. J. Med.* 360, 2616–2625.
Spackman, E., D. A. Senne, S. Davison, and D. L. Suarez, 2003: Sequence analysis of recent H7 avian influenza viruses associated with three different outbreaks in commercial poultry in the United States. *J. Virol.* 77, 13399–13402.
Vourc'h, G., V. E. Bridges, J. Gibbens, B. D. DeGroot, L. McIntyre, R. Poland, and J. Barnouin, 2006: Detecting emerging diseases in farm animals through clinical observations. *Emerg. Infect. Dis.* 12, 204–210.
World Health Organization, 2005: International Health Regulations (2005), 2nd edn. WHO Press, Geneva, Switzerland.
Wurtz, R. M., and M. L. Popovich, 2002. Animal Disease Surveillance: A Framework for Supporting Disease Detection in Public Health. White Paper WHP027. Scientific Technologies Corp., Tucson, AZ.

